(12) UK Patent Application (19) GB (11) 2 366 385 (13) A

(43) Date of A Publication 06.03.2002

(21) Application No 0021480.9

(22) Date of Filing 01.09.2000

(71) Applicant(s)
AB Automotive Electronics Limited
(Incorporated in the United Kingdom)
Forest Farm Industrial Estate, Whitchurch, CARDIFF, CF4 7YS, United Kingdom

Sensatech Limited
(Incorporated in the United Kingdom)
Brighton Business Centre, 95 Ditchling Road, BRIGHTON, Sussex, BN1 4ST, United Kingdom

(72) Inventor(s)
Anthony Moon
Thomas William Bach

(74) Agent and/or Address for Service
Marks & Clerk
57-60 Lincoln's Inn Fields, LONDON, WC2A 3LS, United Kingdom

(51) INT CL^7
H03K 17/955 // B60R 19/48 , G01B 7/02

(52) UK CL (Edition T)
G1N NCTL NDPQ N18A3 N19B2B N19D10 N19D12R N19H7A N19X5

(56) Documents Cited
GB 2286247 A GB 2255641 A
US 5172065 A

(58) Field of Search
UK CL (Edition R) G1N NCTH NCTL NDPQ NDPX
INT CL^7 B60R 19/48 , G01B 7/02 , H03K 17/955
Online: WPI, EPODOC, JAPIO

(54) Abstract Title
Controller for a capacitive sensor

(57) A capacitance detector circuit (40) for use in detecting the proximity of objects and as a collision avoidance device in a vehicle comprises a clock (41), providing a first signal (51) to one plate of a capacitive sensor (42) and an out of phase signal (53, 54) to a synchronised rectifier unit (45-49) comprising switches (45, 46), low pass filters (47, 48) and amplifier (49). The clocked capacitor plate is connected to the input of the rectifier unit which produces an output signal dependent upon the capacitance of the sensor which is dependent upon its proximity to objects. Guard electrodes are included for improving sensor performance. The detector circuit is controlled by a microcontroller or by analogue circuitry to produce drive signals. Output signals can be used to produce audible warning signals of object proximity.

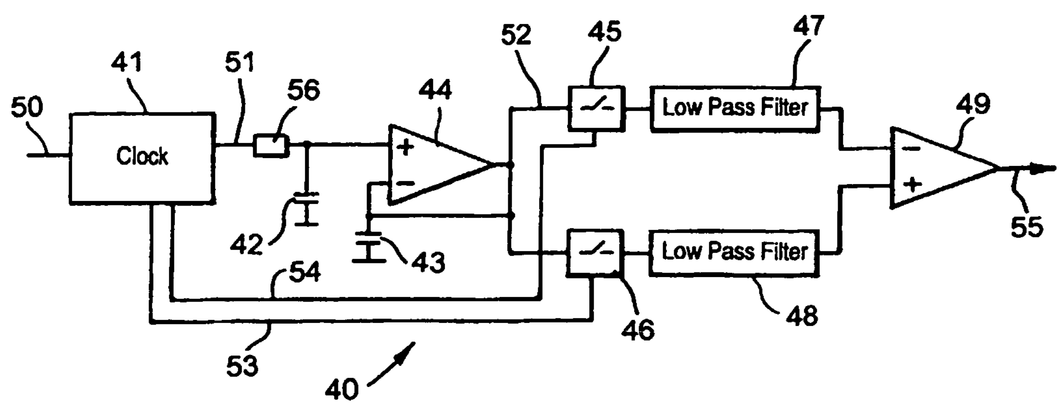

Fig.2

GB 2 366 385 A

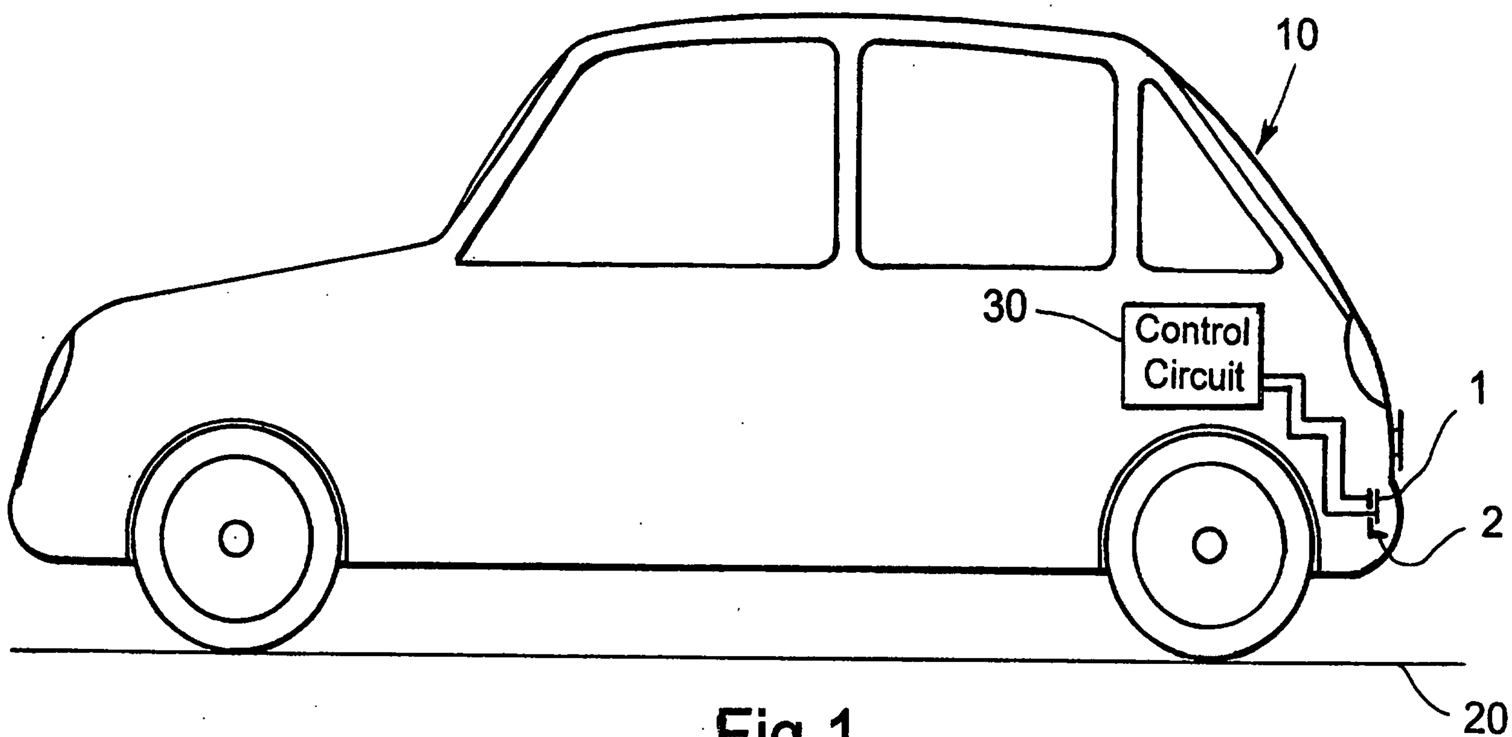

Fig.1

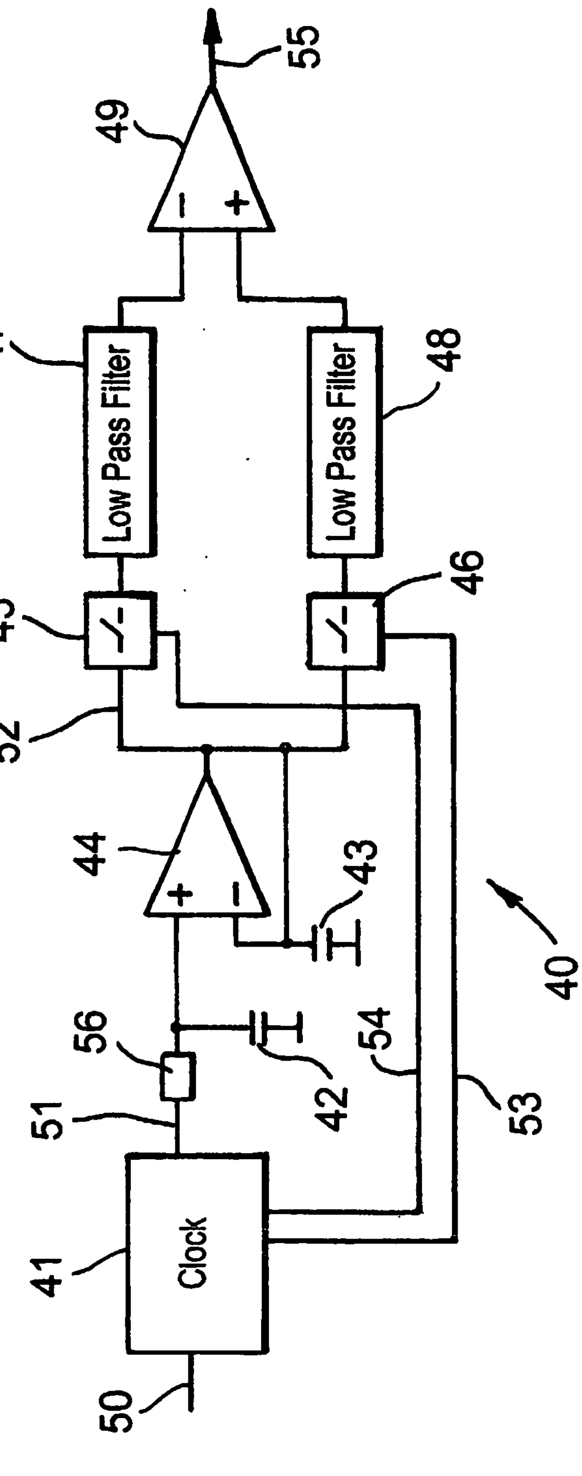
55
49
47
Low Pass Filter
48
Low Pass Filter
45
46
52
44
43
56
42
54
40
51
53
41
Clock
50

Fig.2

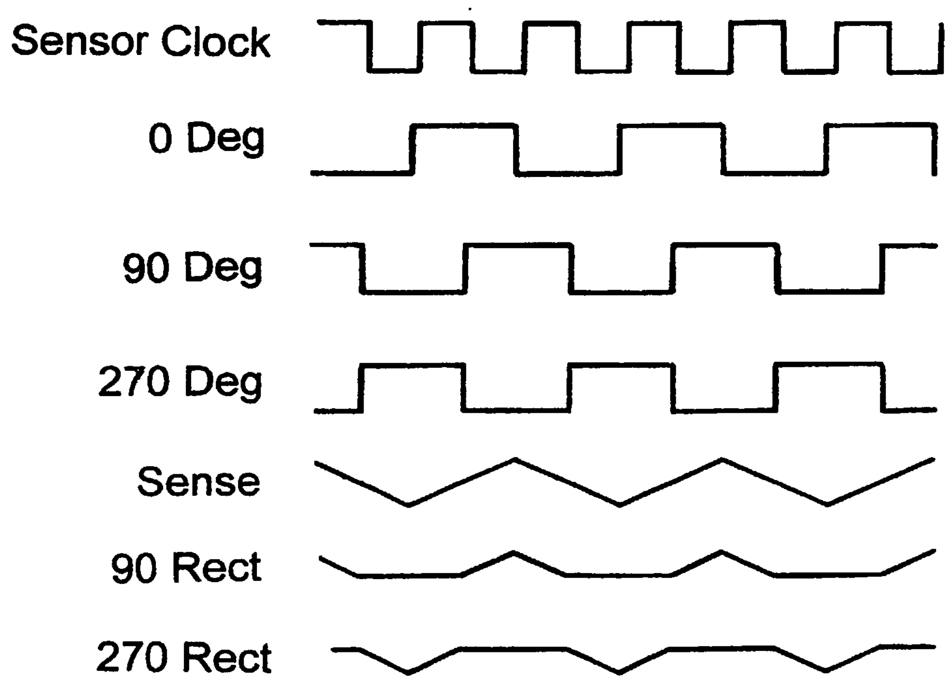

Fig.3

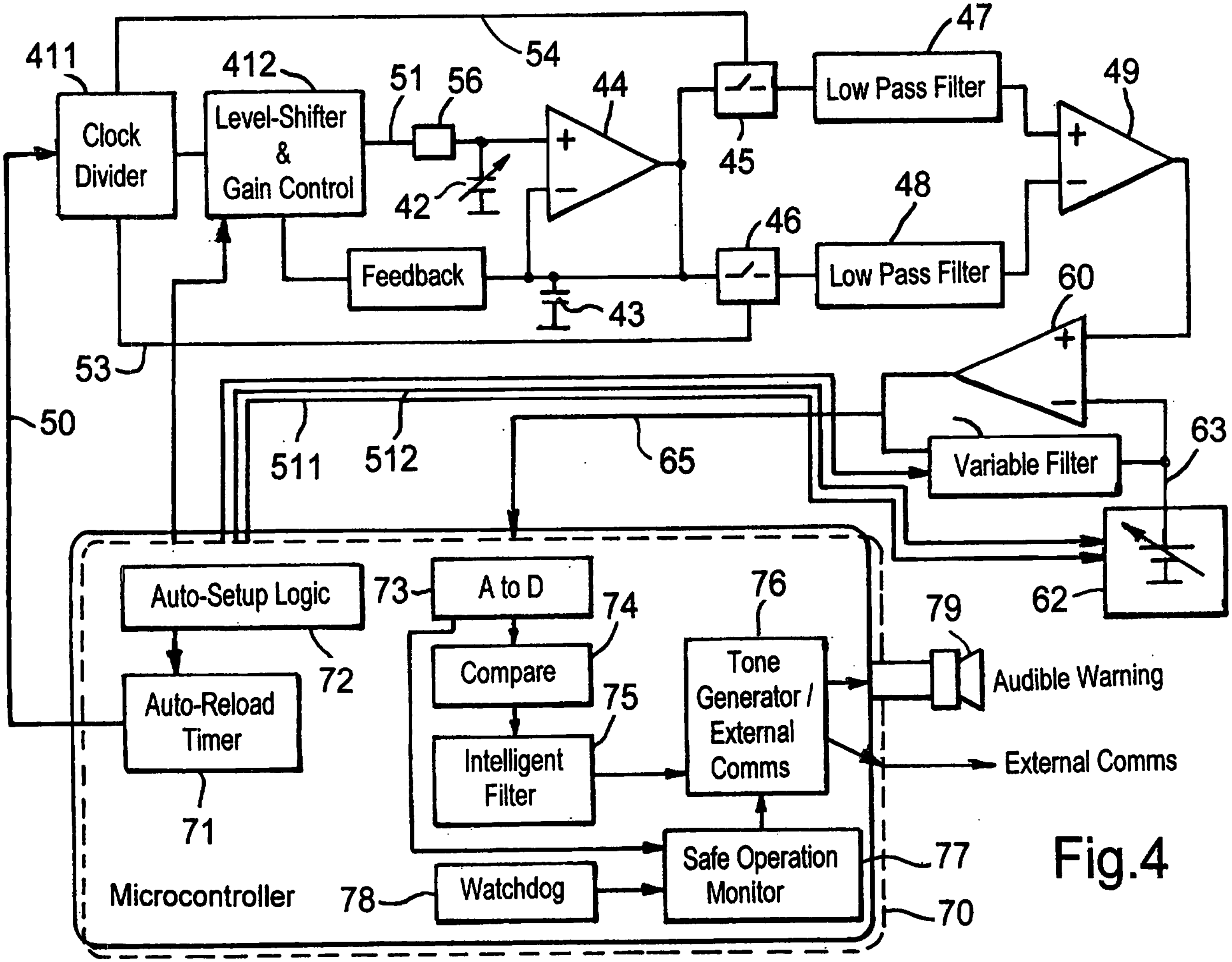
Clock Divider
Level-Shifter & Gain Control
Feedback
Low Pass Filter
Low Pass Filter
Variable Filter
Auto-Setup Logic
Auto-Reload Timer
A to D
Compare
Intelligent Filter
Tone Generator / External Comms
Safe Operation Monitor
Watchdog
Microcontroller
Audible Warning
External Comms
411
412
51
56
54
44
42
43
45
46
47
48
49
60
63
62
53
50
511
512
65
73
74
75
76
72
71
79
77
78
70

Fig.4

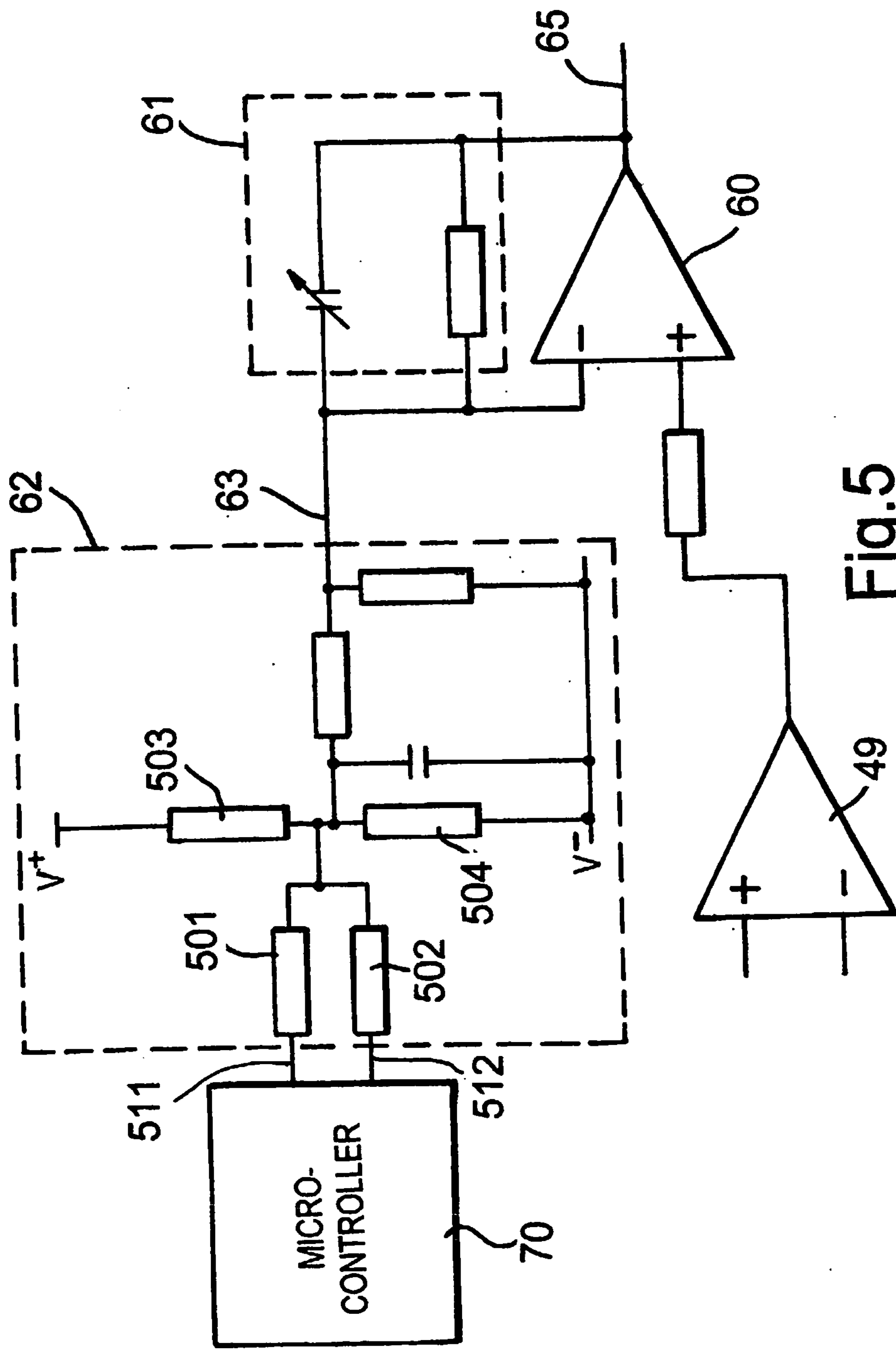

Fig.5

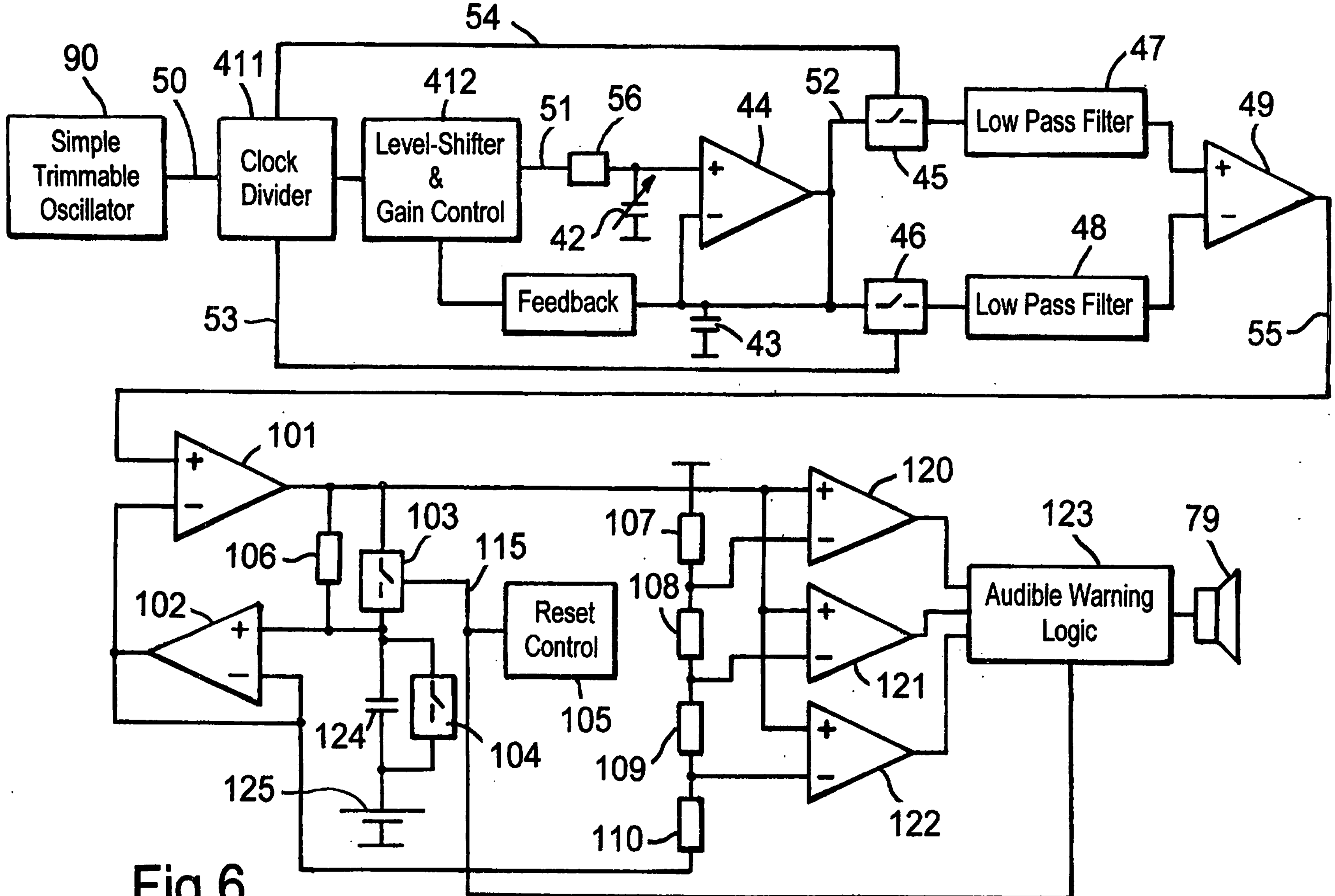
Simple Trimmable Oscillator
Clock Divider
Level-Shifter & Gain Control
Feedback
Low Pass Filter
Low Pass Filter
Reset Control
Audible Warning Logic
90
50
411
412
54
51
56
42
44
43
52
53
45
46
47
48
49
55
101
102
103
104
105
106
107
108
109
110
115
120
121
122
123
124
125
79

Fig.6

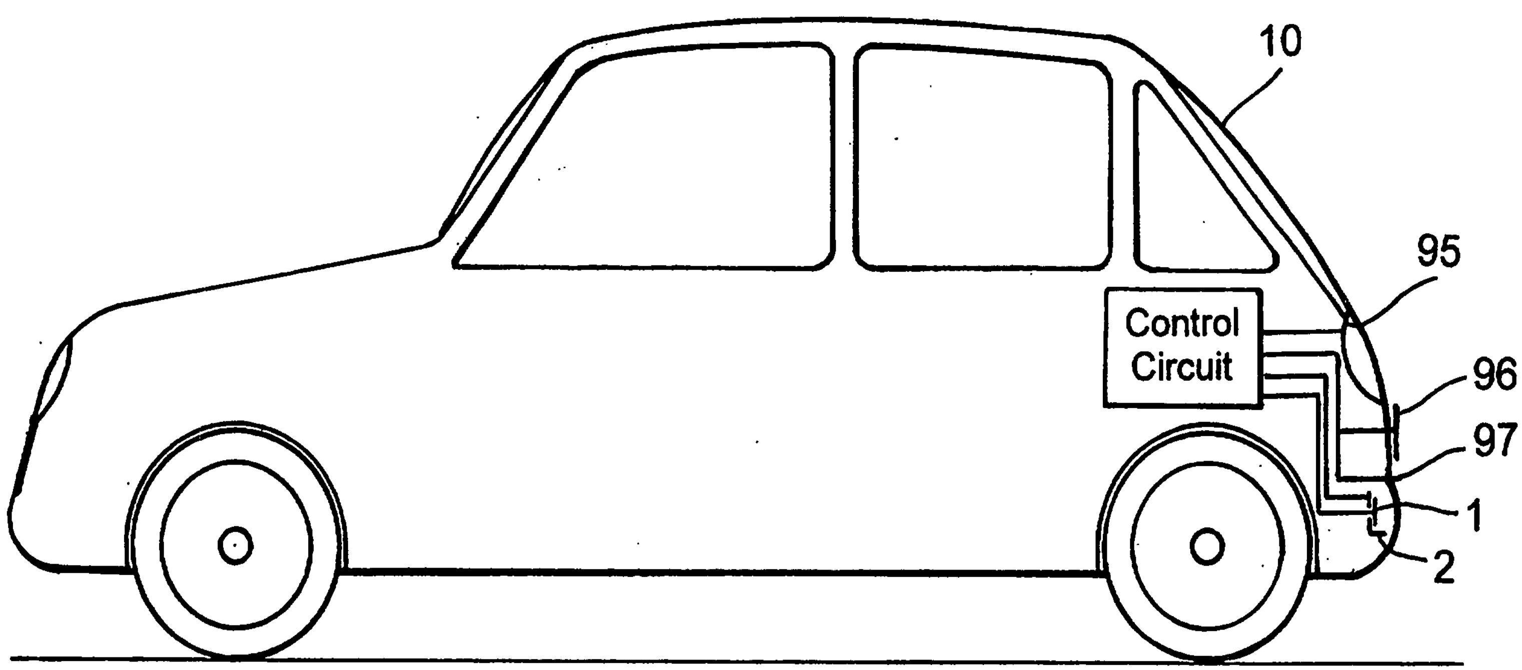

Fig.7

2366385

CONTROLLER FOR A CAPACITIVE SENSOR

This invention relates to an improved capacitive measuring device, particularly for use in detecting the proximity of objects and as a collision avoidance device in a vehicle.

Capacitive proximity sensors are commonly used in industrial applications for locating the presence of materials and performing endstop location. Capacitive sensors have been used for aircraft measurement to the ground at least since the 1940's. More recently capacitive sensors have been used in parts of cars for collision avoidance purposes. These have suffered from a number of problems. They are susceptible to RF noise and are often falsely triggered by other similar capacitive sensors on other nearby vehicles. The radiated field also tends to be too high for conformance with EMC regulations. Water on the sensors has also been a problem as has been the need to locate the sensor electronics in close proximity to the sensor structure.

The installation of a sensor in a vehicle must be easy and fast but the size of the waveform on the sensor should be well controlled to minimise radiated RF noise and to eliminate the possibility of working with too large or small AC signals in the measurement electronics. The system should ideally be fully operational within one second of power being applied. It is also desirable to be able to position the control electronics away from the sensor structure especially in vehicle applications.

Therefore, according to the present invention there is provided a capacitive sensor comprising:

a signal source arranged to produce a main signal and a reference signal, the reference signal being 90° out of phase with the main signal; and

a rectifier unit,

wherein the main signal is fed to a sensor plate connection via a resistance member and the sensor plate connection is connected to the input of the rectifier unit, and wherein

the rectifier unit synchronously rectifies the input signal from the sensor plate connection to provide an output signal.

The main signal is preferably a square wave signal. The reference signal is also preferably a square wave.

The reference signal preferably comprises two signals, one being phase shifted by 90° relative to the main signal whilst the other is preferably phase shifted by 270° (or -90°) with respect to the main signal. The two reference signals are preferably arranged so that they are in anti-phase with each other.

The rectifier unit is preferably arranged to act as a synchronous rectifier. In this case it preferably comprises two switch units which are controlled to switch on and off by being fed with a respective one of the reference signals. The input signal to the rectifier unit is fed to the inputs of each of the two switch units. These can then be selectively switched on in accordance with the reference signal. The outputs from the switch units are preferably fed to a low pass filter before being fed into the inputs of the differential amplifier. In addition, or alternatively, the output of the differential amplifier may be fed through a low pass filter to provide the output signal from the rectifier unit.

The sensor plate is preferably connected to the input of the rectifier unit via an amplifier. The amplifier is preferably a unity gain amplifier. The output of the amplifier is preferably connected to a guard plate. In this way, the voltage on the guard plate is maintained at the same voltage as the sensor plate by virtue of the unity gain amplifier. Thus any change in the potential on the sensor plate will be matched by an equivalent change in the potential on the guard plate. This allows the guard plate to effectively shield the sensor plate from changes going on behind the guard plate without adversely reducing the sensitivity of the device. This also means the leads connecting

the sensor plate to the control circuitry can be shielded by the guard plate connection, using for example co-axial cable, so that the control circuitry can be located away from the sensor plate.

The sensor plate and/or the guard plate may be mounted on a vehicle bumper or other part of the exterior part of a vehicle, but preferably on the outermost part of a vehicle.

The signal source is preferably able to introduce a DC component into the main signal which is helpful in fine-tuning the device in order to overcome variations in the conditions presented to the sensor each time it is operated.

A specific embodiment of the present invention will now be described in detail with reference to the attached drawings in which:

Figure 1 shows a schematic representation of a vehicle with a sensor according to the present invention attached;

Figure 2 shows the basic control and detector circuit of the present invention;

Figure 3 shows representations of the signals in the circuit of Figure 2;

Figure 4 shows a more detailed system of Figure 2 which is controlled using a micro-controller;

Figure 5 shows a circuit suitable for removing a DC offset from the output of the differential amplifier;

Figure 6 shows an alternative construction which avoids the need for a micro-controller; and

Figure 7 shows a schematic representation of vehicle fitted with a modified version of

the present invention which utilises further compensation plates.

A specific embodiment of the present invention will now be described by reference to the use of the sensor on a car for detecting the proximity of objects around the vehicle when the vehicle is being manoeuvred. The sensor is used to provide an indication of the distance of objects from the sensor, which in this example, is located on the bumper of the car, to allow the vehicle to be manoeuvred towards the object without colliding with it. Figure 1 shows a schematic drawing of a figure showing a sensor mounted in the rear bumper of the vehicle for detecting objects around the rear of the vehicle. Whilst in this example, the sensor plate is located on the vehicle bumper, it will be appreciated that this not essential and the sensor could be located in different positions either for convenience of installation or to vary the characteristics of the sensor. However, a bumper provides a convenient position both for installation and for sensing characteristics.

In this device the capacitance of a sensor strip or plate 1, mounted on or inside the bumper of a car 10, is measured and used to detect objects at a distance from the bumper. The sensor strip has a back plane or guard plate 2 between the sensor surface and the car body, driven in conformance with the guard ring principle for reducing the parasitic capacitance.

A clock unit 41 in the detector circuit 40 (see figure 2) generates a square wave AC signal 51 (as shown in figure 3 –'sensor clock')which is fed to the sensor plate 1 through a high value series resistor 56. The capacitance between the sensor plate and ground acts as a series capacitor 42. This capacitor 42 forms an RC circuit with the resistor 56. Consequently, the voltage between sensor plate and ground 20 is an integrated square wave, as shown in figure 3. This integrated square wave is essentially rectified and its amplitude is measured. If the vehicle 10 is reversed towards an obstruction, the capacitance between the sensor plate and ground increases. This has the effect of causing the amplitude of the AC signal across the capacitor 42 to decrease. This change in capacitance is measured to provide an indication of the distance from

any objects to the sensor and hence the vehicle.

The voltage on the sensor plate 1 is fed to an amplifier 44 which then passes the signal 52 to a synchronous rectifier 45,46,47,48,49 to reduce the sensitivity to noise and interfering signals. The signal produced provides an indication of the capacitance of the sensor plate to ground and thus an indication of any objects close to the sensor plate.

The present invention will be described in more detail. Two embodiments are described. The first embodiment (figure 4) utilises a microcontroller 70 to control the various elements of the detector circuit 40 and to process the output to provide indications to the user. The second embodiment (figure 6) uses simple analogue components to provide the drive signal and to process the detected capacitance to provide the output indications to the user. However, the detector circuit in both embodiments operates in a similar manner. The first embodiment will be described first.

To make a device that is sufficiently sensitive, it is necessary to measure small changes in capacitance (< 1pF). Consequently, the changes in amplitude of the measured AC signal are small. When the device is first enabled, the microcontroller 70 therefore adjusts both the frequency and amplitude of the AC signal and also a DC component so that the output from the detector is within a defined range. Typically, the sensor starts with conditions appropriate to a dry bumper with no objects within target range (i.e. minimum capacitance). This requires a moderate amplitude and relatively high frequency.

The clock unit 41 comprises a clock divider 411 and a level shifter and gain control 412. The clock divider 411 is set to the chosen start frequency and the level shifter and gain control 412 are set to minimum gain. The microcontroller 70 measures the output 65 from the DC amplifier 60 via its A to D converter 73 after waiting a suitable settling time. If the measured voltage 65 is too high (close to +5V) it reduces the frequency. This is continued until either the voltage falls to near 0V or it reaches a threshold

frequency that is pre-defined in the software.

If the output voltage 65 falls to near 0V, typically <1.5V, it means that the approximate set-up conditions for the prevailing environment have been found. The microcontroller 70 provides fixed discrete frequencies 50, generated by varying the divide ratio of the system clock. These may be too far apart for optimal tuning, so a second stage of tuning is provided. A variable voltage source 62 produces a DC voltage under the control of the microcontroller 70. This voltage is subtracted from the output from the differential amplifier 49 output by a second differential amplifier 60. The voltage produced by the voltage source 62 is increased or decreased until the input voltage 65 to the microcontroller 70 falls close to zero (typically < 0.3V). The sensor is then set up correctly to sense small increases in capacitance as the vehicle is moved towards an obstruction.

In use, the device signifies this correct set-up state, for example, with a short burst of sound. As an obstruction is approached, the input voltage 65 to the microcontroller 70 increases. This voltage is converted to a digital signal in an A to D converter 73 and compared 73 to reference levels to determine how close the sensor is to an object. The device then provides 75,76 an audible signal through a speaker or sounder 79 or the like. Typically four warnings are used as follows:

Slow broken tone:	Far warning – object > 60 cm away
Rapid broken tone:	Mid warning – object between 30 and 60cm away.
Solid tone:	Near warning – object < 30 cm away

A fourth tone such as a very short burst for 10ms every 2.5 sec can be used to signal to the driver that the parking sensor is active and working correctly.

When stepping through the frequencies, if the microcontroller 70 gets to the lower pre-defined frequency and the measured voltage still remains high (near 5V), then either the sensor is wet or there is an object very close. Consequently, the starting capacitance is

high. In this case, it is necessary to increase the amplitude of the square wave being fed to the RC circuit formed by the resistor 56 and the capacitor 42 formed by the sensor plate 1. The microcontroller 70 increases the amplitude by controlling the setting on the gain control/level shifter 412. The microcontroller 70 then starts at the same high start frequency as before and again steps down through the frequencies looking for the sensor output to drop to less than 1.5V.

The component values are selected such that the microcontroller 70 should find a frequency in which the sensor will work in all but extreme cases. If a correct frequency is found then a short burst of audible warning is issued and the output is monitored as described above.

If the sensor fails to be able to find a suitable frequency for correct operation, then it remains silent. Similarly, if there was a power loss or the sensor fails, then it remains silent. The absence of any audible warnings means that the sensor is not able to operate correctly and the driver is warned to use other means to check that an obstruction is not hit. This could occur either because there is a fault in the sensor or the bumper is covered in so much water, snow or ice that the capacitance is too great for reliable measurements.

The microcontroller 70 uses its auto-reload timer 71 to generate a square wave with a 50% duty cycle of approximately 50kHz. The frequency is controlled by the auto-set-up logic 77. The square wave is fed to the clock divider circuit 411 which produces three outputs of exactly half this frequency with the following phase shifts: 0°, 90°, 270° (see figure 3). The 0° signal is passed into the level shifter and amplitude control 412. This stage is used to ensure that the guard amplifier remains in its linear region, and that the output signal is the correct amplitude for the prevailing conditions. In this embodiment, only two amplitudes are used. The square wave 51 is fed on to the sensor plate 1, whose capacitance to ground is to be measured, through a high value series resistor 56. This has the effect of integrating the waveform (see figure 3 – 'Sense'). The integrated

waveform is fed into a unity gain amplifier 44, which reduces the source impedance of the observed waveform to a point at which the signal can be processed. A feedback loop on the amplifier 44 increases the effective impedance of the resistor 56, so that in practice, it appears to the circuit as having a value of several megohms, although the design needs a resistor of no greater than 1 MΩ. This improves its ability to operate in conditions of damp and high incident EMC. The lower source impedance signal is also fed to the guard plate 2 behind the sensor plate 1 to shield it from changes in capacitance due to objects in directions other than that in which the vehicle is travelling. For example, in the arrangement shown in figure 1, the guard plate 2 shields the sensor plate 1 from sensing forward of the bumper, thus limiting detection to the rear of the vehicle.

The output from the unity gain amplifier 44 is passed into a synchronous demodulator or rectifier 45-49. This consists of a pair of analogue switches 45,46, which are driven by the 90° & 270° signals 54,53 respectively. They chop the waveform as shown in figure 3 '90 Rect' and '270 Rect'. The outputs from the two analogue switches 45,46 are passed into a pair of identical low pass filters 47,48, and the filtered signals are then fed to the two inputs of a differential amplifier 49, whose gain is low at anything above very low frequencies.

The advantage of this circuit is that any interfering signals that are not exactly in phase with the clock create common mode noise to the differential amplifier which is not amplified and therefore rejected.

The output from the differential amplifier 49 is a measure of the amplitude of the AC signal seen at the capacitor being measured. If the capacitance 42 increases, then the amplitude of the AC signal decreases. The polarity of the differential amplifier is such that this causes its output voltage to rise. The output signal is typically a DC voltage biased at about 1.5V DC which rises when the capacitance between sensor plate and ground increases.

The next stage 60,61,62 carries out two functions, namely the removal of the DC offset of approximately 1.5V and further amplification and filtering. The amplifier 60 has a gain of about 20. The offset is removed by subtracting a reference voltage produced by a variable voltage source 62. The voltage produced is controlled by the microcontroller 70.

An example of a circuit for producing the variable voltage is shown in figure 5. Two outputs 511,512 from the microcontroller are used to control the desired output voltage 63. They can modify a DC voltage produced at the mid-point of a divider chain of two resistors 503,504 by being switched to one of low output, tristate or high output. By making the resistors 501,502 in series with the outputs 511,512 have different values, it is possible to arrange for the DC offset 63 to be adjusted to have one of nine values.

The DC offset from the differential amplifier 49 is largely removed by this means. The output 65 of the final stage DC amplifier 60 is set by adjusting frequency, amplitude and DC offset to approximately 0.2V. If the capacitance increases, this voltage rises. This amplifier is provided with a low-pass filter 61 feedback loop. During set-up this filtering is reduced to assist in setting up the required voltage levels quickly. However, once the amplifier has been set up, the low-pass filtering is greatly increased by controlling the variable filter 61. The output from the DC amplifier 65 is fed into an analogue to digital converter 73 for analysis by the microcontroller.

Further low pass filtering can be carried out in software 75. Audible warnings are generated if the converted and filtered signal exceeds pre-programmed thresholds as described above.

The system may be further modified to compensate for drift in the output due to envoironmental changes, etc. After the initial setup of the sensor, a voltage is measured

via the A to D converter. This reference voltage is "remembered" by the microcontroller. In use, as the output 65 of the sensor increases by more than pre-programmed amounts above this reference voltage, then appropriate audible warnings are triggered. However, changes in the environment e.g. temperature can cause the output voltage to drift slowly over time. To compensate for this, the reference voltage is adjusted to track this drift. This is done by allowing the reference voltage to track the actual voltage from the sensor very slowly, much more slowly than the rate of change seen when reversing. Thus changes due to objects moving relative to the sensor will still trigger the sensor normally. However, the slower changes due to envoironmental effects will cause the reference to be adjusted to a new value such that any diiference between the current output and the original reference do not give a false reading because the reference has been updated in the interim. This correction can be carried out in the hardware or by an algorithm in the software to track the sensor output.

The device may drive its own audible warning device 79 but it may be preferable to implement the audible warnings by means of a speaker or buzzer shared with other functions in the vehicle. In such a case, the microcontroller will merely generate one of four signals to the module controlling the audible warning. Three of these will signify that an obstruction has been detected and its approximate range (corresponding to far, mid and near tones). The fourth will be a signal sent at regular intervals to indicate that the sensor is functioning correctly. This signal will deliberately be absent if the microcontroller cannot set the sensor up correctly and also if it loses power for any reason. The module, which controls the audible warning, will then have the responsibility to the driver to indicate that the parking sensor is unavailable.

A second embodiment of the invention will now be described with reference to figure 6. This embodiment avoids the use of a microcontroller 70 to control the frequency and amplitude applied to the sensor plate 1. In this embodiment, the oscillator is a simple RC oscillator 90 that produces the clock signal 50 that drives the clock divider at a fixed frequency. It can optionally be made trimmable by making either the R or C adjustable.

The circuit uses a different means to adjust itself to the environmental conditions, as described below.

The reset control circuit 105 senses when power is first applied. After a short initial delay for the power supply to stabilise and settle down, its output 115 goes high. This has two actions. Firstly, the switch 103 is turned on and secondly, a continuous audible warning tone is generated by the audible warning logic 123.

The input 55 to the DC amplifier 101 is inversely proportional to the amplitude of the rectified AC waveform on the sensor plate. Thus, if the capacitance between the sensor plate and ground increases then the input voltage 55 increases. The switch 103 transfers the output voltage from the amplifier 101 on to a large capacitance, low leakage capacitor 124, the other side of which is connected to a DC reference voltage 125. The purpose of connecting a DC reference to the other side of the capacitor 124 is to minimise the voltage placed across the capacitor so that dielectric absorption effects are minimised. The value of the DC reference is selected so that in use, the voltage across the capacitor is minimised for the majority of operating conditions.

After a delay, typically 1 second, the output from the reset control circuit 105 goes low which turns off both the audible warning 123 and the analogue switch 103. The capacitor is then effectively isolated from the output of the DC amplifier. The capacitor stores the DC voltage to which it was initially charged, which corresponds to the capacitance measured at the sensor plate soon after power was applied to the unit (i.e. when device is first engaged). The stored voltage is converted to a low impedance signal via a source-follower amplifier 102, and fed to the inverting input of the DC amplifier 101 and also to a chain of voltage divider resistors 107,108,109,110. The other end of the divider chain is connected to the supply voltage to provide three intermediate voltages which are fed to the three voltage comparators 120,121,122. The output from the DC amplifier 101 is also fed to the three comparators. The outputs from the three comparators provide an indication of whether the output for the DC amplifier is above or below the three reference voltages.

Once the device is set up, if the output of the DC amplifier increases from its initial value due to an increase in capacitance at the sensor, its output voltage increases. This increase is compared with three threshold voltages determined by the values of the resistors 120,121,122 in the voltage divider chain. If the output increases above any of the three threshold voltages, then an appropriate audible tone is generated by the audible warning logic.

A high value resistor 106 in parallel with the analogue switch 103 enables the stored voltage on the capacitor 124 to track very slow changes in the output of the DC amplifier that would be caused by drift and temperature changes which might otherwise trigger a false alarm.

If the sensor has higher capacitance than normal, due, for instance, to rain on it, then the initial output of the sensor is higher than its normal value (typically less than 1 Volt). This initial value is stored and its value at any subsequent time is compared to the value stored on the storage capacitor.

The use of a push switch 104 adds the feature of an easy, inexpensive set-up for any particular bumper without the need of any calibration or test equipment. This puts a defined voltage reference on the capacitor 124. The instructions to the fitter are then to adjust the frequency control until the sounder gives either a slow or fast pulsing tone. This ensures an intentional lack of accurate set-up of the frequency. This ensures statistically that each set-up frequency, even on identical bumpers, will be different due to variations in components and human, robot or mechanical trimming. This ensures that systems on nearby bumpers will not interfere, as the narrow band synchronous demodulator will not demodulate the electric field from the nearby system.

In a further aspect of the present invention, the range and sensitivity of the capacitive sensor can be increased by applying an electric field in such a way as to enhance the signal received by the sensor. This is achieved by applying an output from the 90^{o}

reference signal to a suitable conductor above the sensor on the bumper. Such a conductor might be the number plate, a metalised finisher clipped to the bumper, such as a chrome strip, or even the reflecting surfaces in the lamp cluster. The application of the signal to such a surface has the effect of increasing the sensitivity of the sensor.

By applying the 270° reference signal to a conductor low down, or to the sides of the sensor, sensitivity in those directions can be reduced. Thus sensitivity of the sensor plate to changes in vehicle height or to objects to the side of the vehicle can be reduced by this means. This avoids the need for additional sensors separate to the main sensor to cancel out effects of the car getting nearer the ground or to objects at the side of the vehicle. For example where an additional capacitive sensor might have been used, with this system, this is not necessary. No additional electronics is needed either to measure the capacitance of an extra plate at a different and non-interfering frequency and combine the data with that of the main capacitive sensing plate, or to time multiplex the data and subtract to cancel out the effects of the car getting nearer the ground. This similarly applies to the plate driven at 90°.

The placing of the 90° signal plate above the sensor and the 270° signal plate below the sensor is the optimal arrangement. Other less optimal arrangements that also work well are with the 90° signal plate in the middle of the bumper or at the bottom of the sensor with the 270° signal plate below.

An exemplary embodiment of the present invention has been described taking into account projected cost and performance trade-off. However, it will be appreciated that this invention is equally applicable to the use of separate plates or the incorporation of these features into one plate and the collection of data separately in a time or frequency domain from these plates. This separate collection would allow increased sensing performance, but with increased complexity, as the plates can be driven optimally for the task to be performed. When either the 90° signal plate above the sensor or the 270° signal plate below the sensor is used, the sensor plate is now used only as a receiving plate. In this function a charge amplifier using a virtual earth input can give improved performance and would be used in such an embodiment.

CLAIMS:

1. A capacitive sensor comprising:

a signal source arranged to produce a main signal and a reference signal, the reference signal being 90° out of phase with the main signal; and

a rectifier unit,

wherein the main signal is fed to a sensor plate connection via a resistance member and the sensor plate connection is connected to the input of the rectifier unit, and wherein

the rectifier unit synchronously rectifies the input signal from the sensor plate connection to provide an output signal.

2. A capacitive sensor according to claim 1 wherein the main signal is a square wave.

3. A capacitive sensor according to claim 1 or 2 wherein the reference signal is a square wave.

4. A capacitive sensor according to any one of claims 1-3 wherein the reference signal comprises two signals, one having a phase 90° advanced relative to the main signal and the other having a phase 90° retarded with respect to the main signal.

5. A capacitive sensor according to claim 4 wherein the two reference signals are in anti-phase with each other.

6. A capacitive sensor according to claims 4 or 5 wherein the rectifier unit comprises first and second switch units, each switch unit being fed with the input signal and a respective one of the reference signals and wherein the outputs of the switch units are fed to the inputs of a differential amplifier to provide the output signal.

7. A capacitive sensor according to claim 6 wherein the outputs of the switch units are fed to the differential amplifier via low pass filters.

8. A capacitive sensor according to claim 6 or 7 wherein the output of the differential amplifier is passed through a low pass filter to provide the output signal.

9. A capacitive sensor according to any one of the preceding claims wherein the sensor plate connection is connected to the input of the rectifier unit via an amplifier.

10. A capacitive sensor according to claim 9 wherein the amplifier has a gain of substantially one.

11. A capacitive sensor according to any one of the preceding claims wherein the main signal comprises a DC component.

12. A capacitive sensor according to claim 10 wherein the output of the amplifier is connected to a guard plate.

13. A capacitive sensor according to claim 12 further comprising a sensor plate connected to the sensor plate connection and wherein the sensor plate and the guard plate are mounted on a vehicle bumper.

14. A capacitive sensor according to any one of the preceding claims wherein a predetermined DC offset is removed from the output signal.

15. A capacitive sensor according to claim 14 wherein the predetermined offset is determined when the sensor is powered up.

16. A capacitive sensor according to any one of the preceding claims further comprising means for compensating for drift in the output signal.

17. A capacitive sensor according to any one of the preceding claims wherein the frequency of the signal source is selected according to the conditions present when the sensor is powered up.

18. A capacitive sensor according to any one of the preceding claims further comprising one or more compensation plates connected to the or a reference signal.

19. A capacitive sensor according to claim 18 when dependant on claim 4 comprising two sets of one or more compensation plates, one set being connected to one reference signal and the other set being connected to the other reference signal.

20. A capacitive sensor substantially as described herein with reference to and as shown in the attached drawings.

21. A vehicle comprising a capacitive sensor according to any one of the preceding claims.

17

The Patent Office

INVESTOR IN PEOPLE

Application No: GB 0021480.9
Claims searched: All

Examiner: Simon Colcombe
Date of search: 19 December 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): G1N (NCTH, NCTL, NDPQ, NDPX)

Int Cl (Ed.7): B60R, G01B, G01S, H03K

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2286247 A	(MIT) Whole document.	1-3 at least
X	GB 2255641 A	(TSUDEN) Whole document.	1-3 at least
X	US 5172065	(WALLRAFEN) Whole document.	1-3 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		